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ON A MONOSPECIFIC ASSEMBLAGE OF SAUROPOD DINOSAURS FROM PATAGONIA: IMPLICATIONS FOR GREGARIOUS BEHAVIOR

Rodolfo A. CORIA

Museo Carmen Funes. (8318) Plaza Huincul, NEUQUÉN. ARGENTINA

ABSTRACT: **A monospecific bone bed of the cetiosaurid sauropod *Patagosaurus fariasi* is reported. Its implications for hypotheses of dinosaur gregarious behavior are discussed. Taphonomic data suggest catastrophic mass accumulation of the assemblage. Associated juveniles and adults suggest the remains of a social group or herd, and might suggest extended parental care among cetiosaurids.**

RESUMO: **Neste artigo é referenciada uma camada com abundantes restos osteológicos de apenas uma espécie de saurópode do grupo dos cetiossaurídeos, *Patagosaurus fariasi*, e discutem-se as hipóteses de comportamento gregário nos dinossáurios. Os dados tafonómicos permitem-nos inferir que o conjunto de ossos resultou de uma acumulação catastrófica. A presença de juvenis e de adultos sugere que se tratava de uma manada de dinossáurios e provavelmente que os cetiossaurídeos dispensavam cuidados aos juvenis.**

INTRODUCTION

The gregarious behavior and habits of dinosaurs have received much less study than their functional morphology. This is because information on the gregarious behavior of these enormous terrestrial vertebrates cannot be obtained simply from the analyses of their anatomy. Consequently, almost all evidence used to infer dinosaur gregarious behavior comes from fossil tracks, nestsites and monospecific assemblages.

BIRD (1944), on the basis of footprints, was the first to consider the possibility that sauropod dinosaurs congregated in herds. Many latter authors agreed with his interpretation (BAKKER, 1968; OSTROM, 1972, 1986; LOCKLEY, YOUNG & CARPENTER, 1983; LOCKLEY, 1991).

During the summers of 1978-1980, paleontologists from the Fundación Miguel Lillo, the Universidad Nacional de Tucumán, the Museo Argentino de Ciencias Naturales, and the Consejo Nacional de Investigaciones Científicas y Técnicas, headed by Dr. José Bonaparte, found the remains of five specimens of cetiosaurid sauropods from a Middle Jurassic locality at Cerro Cóndor Norte (Chubut Province, Patagonia, Argentina) (Fig.1).

The preliminary taphonomic and population analysis of this bonebed of cetiosaurid sauropods presented here, was briefly reported previously by BONAPARTE (1982) as a family-like group of sauropods. This report may be considered a further attempt to provide information about the social habits of these huge animals.

MATERIALS – SPECIMENS USED IN THIS STUDY[1]

The materials that compose each specimen and the interpretations of their ontogenic stage are presented below. Identification and discrimination of each individual specimen was made on the basis of size and taphonomic distribution of the fossils (BONAPARTE, *pers. commun.*). The specimens (individuals) are described in order of decreasing size.

SPECIMEN 1 (PVL-4170 HOLOTYPE)

Four anterior cervicals, three posterior cervicals, three articulated anterior dorsals, five mid and posterior dorsals, two proximal caudal centra, twelve mid

(1) Abbreviations: MANC-CH - Museo Argentino de Ciencias Naturales, Chubut Collection. PVL - Vertebrate Paleontology Lillo Institute.

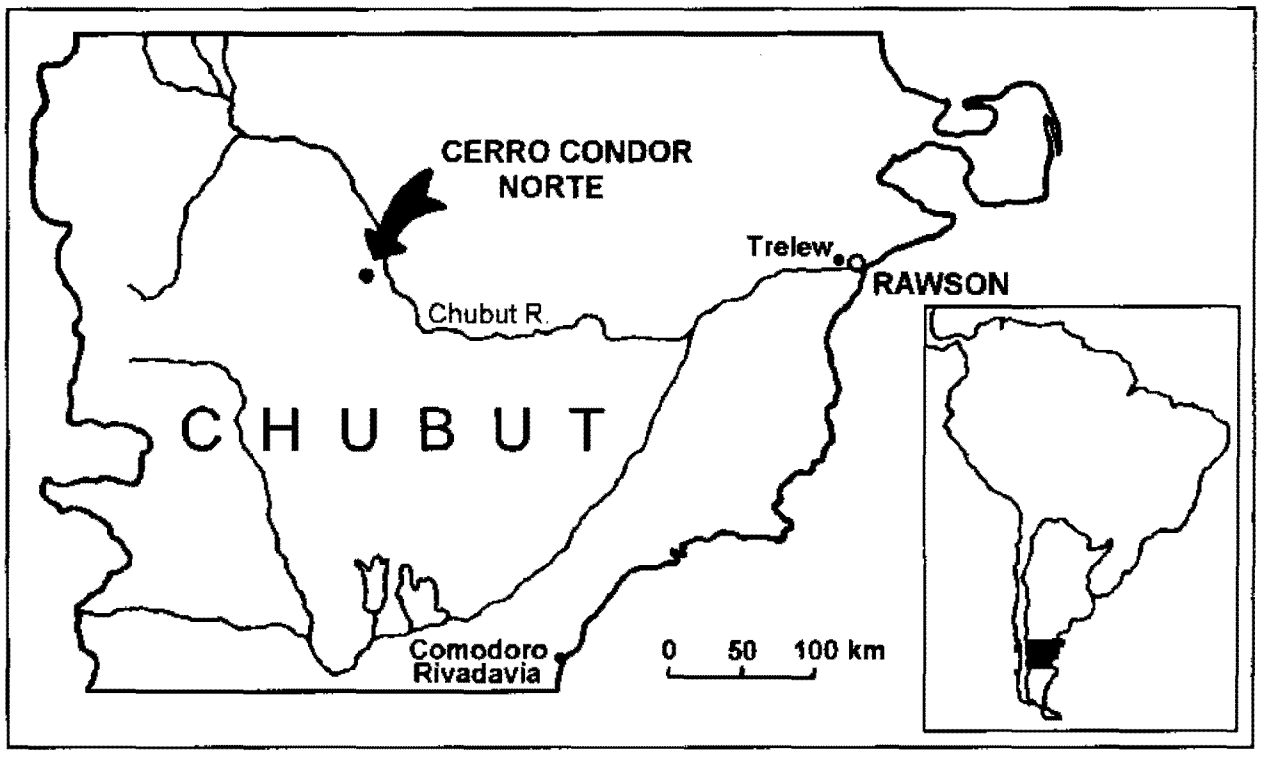

Fig. 1 - Map of Chubut Province, showing the location of Cerro Condor Norte locality.

and distal caudals, rib fragments, chevrons, right scapula (proximal part) and coracoid articulated, left scapula and coracoid, left humerus (proximal part), both ilia, both ischia (partially fused and incomplete proximally), right pubis, both femora. This specimen is believed to be an adult because the neural arches are coossified to the centra and sacral vertebrae coossified. It represents a large specimen, with a femur 1364, and a pubis 835 mm long.

SPECIMEN 2 (PVL-4116 AND MACN-CH-935)

Four middle dorsal neural arches, three dorsal centra, four sacral centra with sacral ribs, one sacral centra, three sacral neural arches, only one preserving both transverse processes, one proximal caudal centrum, one proximal caudal arch, six mid and distal caudal vertebrae, two incomplete neural spines, six proximal fragments of dorsal ribs, three chevrons, fragments of both ilia, both pubis and ischia. This is also considered an adult individual based on its large size. However, the neural arches are not coossified with their centra, nor are the sacral centra coossified to each other. This individual, with a pubis 803 mm long, is smaller than specimen 1.

SPECIMEN 3 (PVL-4172 AND MACN-CH-932)

Axis neural centrum, middle cervical centrum, two cervical centra, dorsal centrum, anterior dorsal, three dorsal centra, six dorsal neural arches, eight dorsal centra, one sacral vertebrae with a neural arch, one sacral rib, right scapula and coracoid, right humerus, radius and ulna, both pubes, three metatarsals, two mid-falanges, one ungual.

This individual is considered a juvenile because the presacral and sacral neural arches are not fused to their centra. This specimen is smaller than Specimen 2, having a pubis 548 mm long.

SPECIMEN 4 (PVL-4171 AND MACN-CH-933)

Anterior portion of a left dentary, two cervical centra, anterior dorsal centrum, seven dorsal centra, four dorsal neural arches, one sacral neural arch, ilium fragment, left pubis, right femur and tibia. The unfused neural arches and the size of apendicular bones indicate juvenile condition. The pubis is 414 mm long and the femur 650 mm long.

SPECIMEN 5 (PVL-4615)

One dorsal centrum, one incomplete ischium. The ischium is estimated to have been 320 mm long, indicating the smallest individual in the assemblage.

DESCRIPTION

PALEOENVIRONMENT

The fossil-bearing strata is a thinly bedded calcareous tuff containing carbonaceous plant remains, and intercalated with thin sandstones. The paleoenvironment was a floodplain with abundant water (BONAPARTE, 1986). The remains show no high energy transport because the dorsal arches of young in-

dividuals still preserve their delicate infradiapophysial and parapophysial-diapophysial laminae. Moreover various bones remain in articulation (Fig. 2). Although a detailed sedimentological study of the quarry has not been made, a preliminary analysis of the sediments and the preservation of articulated, and delicate and small bones indicate a low energy environment.

TAPHONOMY

The specimens were found in a area 15 m long and 4 m wide (BONAPARTE, 1986), and were mostly disarticulated and embedded at the same stratigraphical level (Fig. 2). Practically all of the material consists of postcranial bones. The only cranial fragment is a portion of the left dentary of a juvenile (Specimen 4, MACN-CH-933). The absence of cranial bones may be due to incomplete ossification of the bones, *post mortem* scavenging or erosion. It should also be noted that the amount of material for each individual is less in the younger individuals. Taphono-mic biases (*e.g.* immature/small bones weather more rapidly than adult/large bones; see BEHRENSMEYER, 1978; BEHRENSMEYER, WESTERN & BOAZ, 1979; CARPENTER, 1982) might explain the usual scarcity of juvenile bones (RICHMOND, 1965; LEONARDI, 1981).

The whole assemblage shows no great variation in the stage of weathering. Bones of the same weathering stage may, in some cases, be used as an evidence of catastrophic accumulation (VOORHIES, 1969; BEHRENSMEYER, 1978). All five sauropod specimens belong to the same species, *Patagosaurus fariasi* BONAPARTE, 1979. This identification for four of the specimens is based on the morphology of the vertebrae, which agrees with Bonaparte's specific diagnosis (BONAPARTE, 1986). Although the vertebral remains of Specimen 5 are not sufficient for a specific identification, for this paper, I propose to assign this specimen to this same species because the ischium shows the same morphology as the other specimens. No other vertebrate taxa were associated with the material described here, indicating a monospecific assemblage of cetiosaurid sauropods.

POPULATIONAL ASPECTS

This assemblage is composed of both adult and juvenile individuals in different stages of ontogenic development. Because so few preserved elements are common to all five individuals, the relative length of the pubis was used to show the size/age classes presented in Figure 3. In the diagram, two groups may be seen, one formed by Specimens 1 and 2 representing the adults; the other formed by Specimens 3, 4 and 5, which represent juveniles. The adult specimens are the largest individuals known for *Patagosaurus fariasi*. Specimens 3, 4 and 5 are considered juveniles because of their smaller size compared to Specimens 1 and 2. Also, the vertebral centra and neural arches are not fused, indicating a juvenile condition. Curiously, Specimen 2 is adult in size (compared with Specimen 1), but it shows juvenile characteristics due to the unfused centra and neural arches. It is possible that complete coossification of the vertebrae in these animals occurred in later stages of life. Alternatively it could be an example of sexual dimorphism with the female showing a juvenile condition, as in some large living ungulate mammals (*e.g.* bison).

DISCUSSION

Gregarious behavior has been frequently inferred from a monospecific dinosaur bonebed. Two such examples are the *Iguanodon* bonebed from Bernissart, Belgium (DOLLO, 1882), and the *Plateosaurus* bonebed from Trössingen, Germany (HUENE, 1928). However, these cases are now interpreted as accretional, not catastrophic assemblage of dinosaurs (COOMBS, 1990), due to the stratigraphic relationships of individual skeletons. In South America, in the Triassic

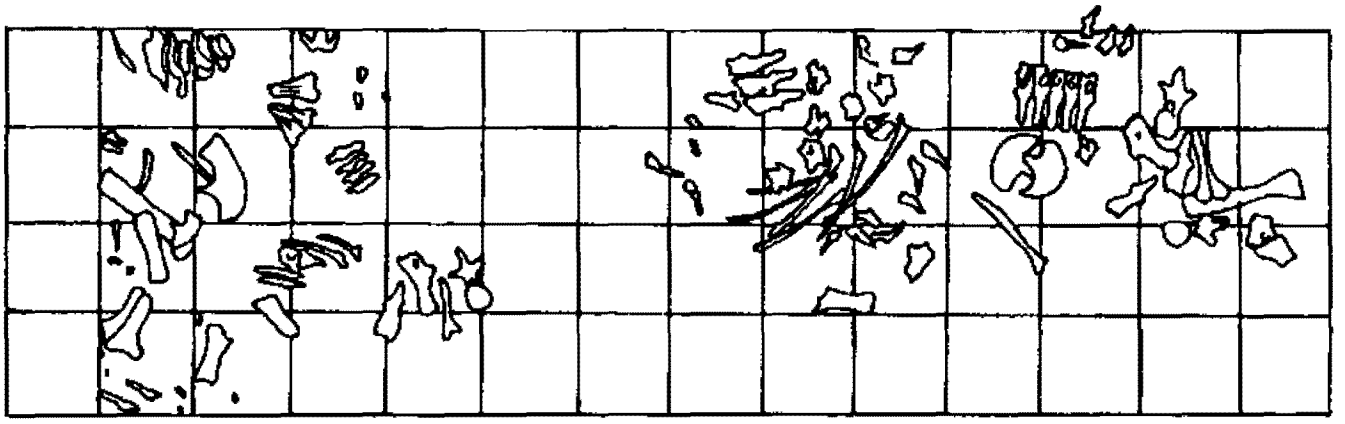

Fig. 2 - Map of the distribution of the principal pieces of *Patagosaurus fariasi* found in Cerro Condor Norte (after BONAPARTE, 1986). Quadricule: 1 m by side.

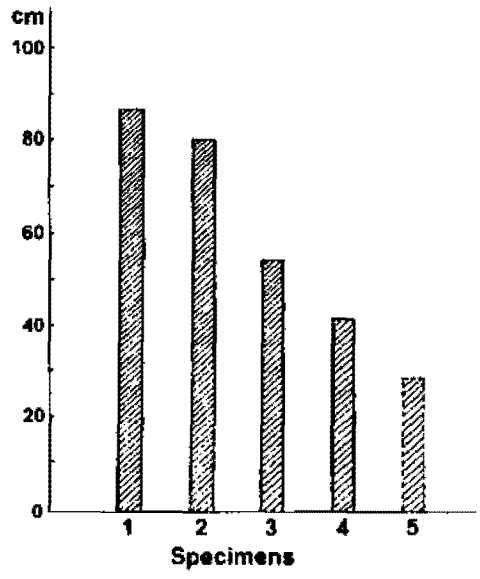

Fig. 3 - Size/age distribution of the assemblage estimated from the pubis length (Specimen 5: estimated). See text for identification of specimens.

El Tranquilo Formation at Estancia Laguna Colorada, Santa Cruz Province, Argentina, many specimens of *Plateosaurus* sp. were found together (CASAMIQUELA, 1964; BONAPARTE, 1978). Sedimentological and paleoenvironmental studies of this locality will be useful to determine if this mass-accumulation is due to catastrophic or accretional conditions.

The preservation stage of the assemblage from Cerro Cóndor Norte indicate similar condition of exposure to weathering, burial at the same stratigraphic level and a relatively high proportion of juveniles with respect to adults. All these factors suggest, but do not prove, a catastrophic accumulation of the bones.

The monospecific nature of the Cerro Cóndor Norte sauropod assemblage also suggests the possible coexistence of adults and juveniles of different ages, perhaps in some kind of gregarious group or herd. Probable evidence of posthatching parental care has come from sites where juvenile and adult specimens were found associated with nest and eggs (*e.g. Protoceratops*, *Maiasaura*, see COOMBS, 1990).

Due to the size of juvenile individuals from Cerro Cóndor Norte (starting with Specimen 5, PVL-4615), it is not possible define them as hatchlings (Fig. 4). No evidence of nest or eggs is known from this locality. If the hypothesis about the catastrophic origin of the assemblage of Cerro Cóndor Norte is correct, it probably indicates that the sauropod species *Patagosaurus fariasi* exhibited gregarious behavior.

CONCLUSION

The fossil assemblage at Cerro Cóndor Norte is believed to represent part of a "herd" of sauropod dinosaurs based on both taphonomic and systematic data. The monospecific nature of the assemblage containing both adult and juvenile specimens suggests mass-accumulation of part of a sauropod herd with a relatively broad size/age association of individuals of the same species. The populational composition of the assemblage suggests also that some cetiosaurid sauropod dinosaurs (*e.g. Patagosaurus fariasi*) could have developed relatively complex social behavior involving posthatching gregarious behavior and parental care extended to young of several age classes.

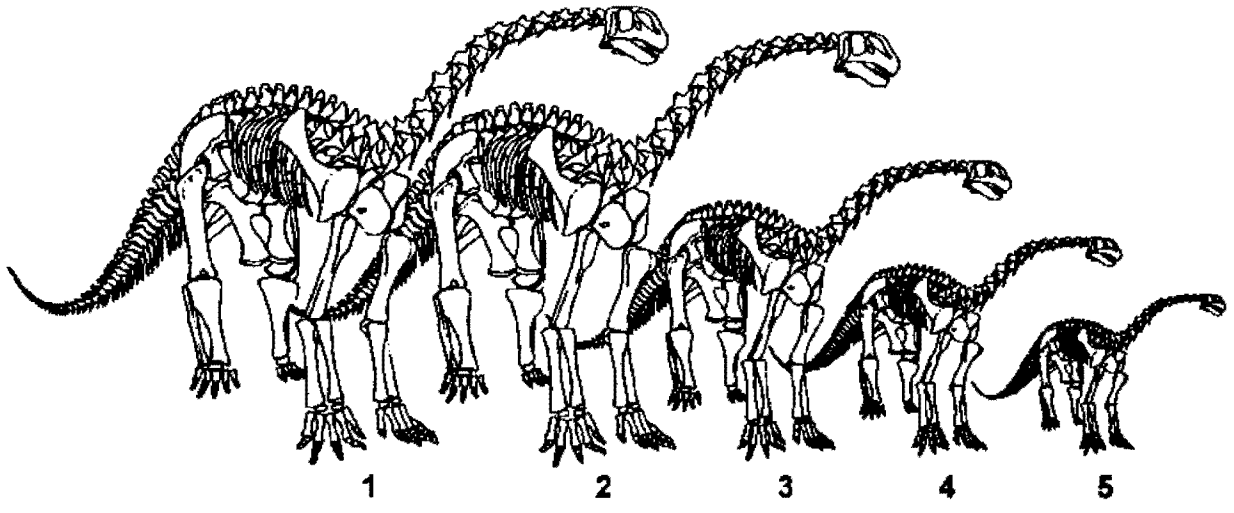

Fig. 4 - Skeletal restoration of the assemblage (restoration of *Patagosaurus fariasi* from BONAPARTE, 1986). See text for identification of specimens.

The herd defense hypothesis proposed for hadrosaurs (LOCKLEY, YOUNG & CARPENTER, 1983), based on both tracks and nesting site evidence (HORNER & MAKELA, 1979) may also be applied to the sauropod *Patagosaurus fariasi*. At present, no anato-mical features which would provide defense have been recognized in this species. Possibly such herding behavior played an important role in the survival of the individual, the population and the species.

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